THE CORALS AND CORAL REEFS OF THE WESTERN WATERS OF THE GULF OF MEXICO.

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One of the peculiarities of Vera Cruz which almost first arrest the eye of the traveler is the vast quantity of coral that has been used in construction. The pier-fronts, the sea-wall, and the more ancient houses show equally the use that has been made of this material, the *piedra de mucar* of the inhabitants. Alexander von Humboldt, in his Essai Politique sur la Nouvelle Espagne, speaks of this *piedra de mucar*, and others after him refer to the same material. The species of coral contained in the rock are mainly *Orbicella cavernosa* (?), *O. annularis*, *Diploria cerebriformis* and *Mœandrina strigosa*, and since these species all inhabit the waters of the warm Atlantic, in and out of the Gulf region, it would seem but natural to assume that the Vera Cruz rock was obtained somewhere in the vicinity of the city. On entering the port on a calm day the growing coral-masses can be distinctly seen from the bow of the vessel, and all around are a number of islets and banks which closer inspection shows to be made up almost entirely of living and dead coral. The larger vessels anchor in the deeper waters that separate the growing banks, while the smaller craft drop their anchors directly on the heads of living coral. The small boat which lands passengers from the steamers carries the traveler directly over a line of reef, whose contours, barely removed more than a pole's length from the eye of the observer, appear sharply defined through the perfectly clear and transparent waters.

In view of the peculiar conditions which surround these reefs, it is difficult to understand how it has come to be the general belief among scientists that coral-reefs are not found in the western waters of the Gulf of Mexico, a belief that has held its own for a period of nearly half a century, or ever since Darwin published his classical work on the "Structure and Distribution of Coral Reefs" (1842). Thus, neither in the first edition of this work nor in the last (1889, edited by Prof. Bonney) is mention made of the occurrence of such reefs, nor do they appear on the map of distribution which accompanies the work. Prof. Dana, writing in 1890 ("Corals and Coral Islands," 3d edition), says: "But the west shores of the Gulf of

Mexico, as well as the northern, like West Florida, are mostly low, and without reefs; they are within the influence of the Mississippi and other large rivers" (p. 352). Can it be assumed that all travelers to the region have so far feared a visitation of the yellow fever as to force them to speed their journey in such a way as not to permit an examination of the ground that was about them? Or has this fear kept scientists away generally? I must admit that the ten days of June which I, in company with my associate, Mr. Frank C. Baker, spent in exploring the reefs and sands of Vera Cruz were all that could have been desired, and neither of us experienced any ill effects from out-door labor. When we were not on the water we were on the hot sands, but the highest registry of the thermometer was only 92° F., and after 10 o'clock in the morning the in-draught of cool air from the sea was such as to render travel and work not only tolerable but pleasant.

The species of coral collected by us are the following:

Madrepora prolifera, Lam.

A very abundantly represented species, rising to within about six feet, or less, of the surface of the water. It corresponds in all essentials of structure with specimens of the same species from the Dry Tortugas and from the Florida Reefs generally.

Madrepora palmata, Lam.

This magnificent species occurs in association with the above, forming heads from five to ten feet, or more, in expanse. It covers large areas in the shallower reef-waters, where its rich brown and yellow colors are seen to great advantage. Many of the older specimens show the palmations in distinct tiers or series, and not merely on a single plane; the crateriform protuberances, largely covering annelid tubes, are very abundant, and give to the corallum a singularly striking and robust appearance.

I feel doubtful if the palmate form of the corallum, as seen in *M. palmata*, *M. flabellum* and *M. alces* (East Indies), is in itself a character sufficient to distinguish the species from those forms, agreeing with the palmate types in other respects, in which the corallum is strictly digitate. My associate, Mr. J. E. Ives, has called my attention to the tendency in the direction of digitation which many individuals of the palmate species exhibit. This is carried so far in some of the specimens contained in the collections of the Academy of Natural Sciences that it becomes difficult, if not really impossible, to class the individuals. The tendency toward digitation shows

itself more particularly on the plane of the frond, and is but rarely marginal.

It seems to me likely that certain special conditions of the environment are directly instrumental in bringing about some of those modifications in outline which have been held to be of specific value; but if such is the case, I was unable in the present instance to determine any governing cause. In the Bermudas I thought that the crowding of the calyces on one side of the stem of *Oculina* was due to the action of local currents, or to one-sided deposit of shore-sediment; and I believe that a similar observation, or one much in harmony with it, has been made in the case of certain digitate species of madrepore.

Porites furcata, Lam.

A number of individuals of this species were found washed up on the shingle banks of the Isla Verde and of Sacrificios Island. The frequency of fragments shows that the species must be abundant, but we failed to find the exact locality of its occurrence. Not unlikely it is in the waters of Anegada Reef.

Porites astræoides, Lesueur.

Abundant among the more massive corals of the inner waters.

Siderastræa galaxea, Ellis and Solander.

Several specimens obtained in the inner waters; also washed up on the beach of the Isla Verde.

Orbicella annularis, Lam.

I identify with this form several rolled or worn fragments, whose partially obliterated characters do not, perhaps, allow of absolute specific determination. This is one of the common forms in the Vera Cruz walls.

I suspect that several of the generally recognized species of *Orbicella* are only varietal types, but the material at my command does not permit me to determine this point with positiveness. The specific characters are drawn in very close limits, and I doubt if they can be made applicable to a large series of individuals of any one group. We dredged undoubted specimens of the *Orbicella annularis* —at least of the form figured as such by Pourtalès in his report on the Florida corals—off the coast of Yucatan, near Progreso, in about 20 feet of water. The cœnenchyma is of a brilliant vermilion color. Neither Dana nor Milne-Edwards mentions the color of the animal,

and it is singular that the latter author states that the habitat of the species is unknown.[1]

Orbicella sp.?

A well-preserved, washed fragment of a subglobose form, whose characters do not seem to fit in with those of any described species. In general appearance it at once recalls *O. annularis*, and not impossibly it may be a variety of that species; but the septa of the corallum are compound, divaricating or trivaricating, and appear in transverse section 24 in number. They are much finer than in typical *O. annularis*, as are also the irregular and multiple cells in the intercalicular wall.

Found on the beach of the Isla Verde.

? **Orbicella cavernosa**, Esper.

Several fragments from Sacrificios Island and elsewhere which I doubtfully refer to this species. The intercalicular spaces are largely cellular, with the form in part of the letter V, and the species thus approaches *O. radiata*, Ellis and Solander. From the latter it is, however, distinguished by the smaller size of the calyces, and by the more compact corallum. In certain respects, again, the species approaches *O. glaucopis*, of Dana, from the Fiji Islands.[2]

This species of coral is largely represented in the wall-structures of Vera Cruz, but a second related species, possibly *O. radiata*, occurs associated with it. We failed to obtain any living *Orbicellæ* in the Vera Cruz waters, and the species are probably most abundant on the outer border of the reef-sea.

Mæandrina strigosa, Dana.

This is one of the two common forms of brain-coral which enter into the construction of the reefs. It forms large orbicular or elliptical heads, four or five feet, or more, in diameter, and shows to great advantage in the shallower waters through its brilliant orange coloring. The basal attachment is often limited in area, and "rotten" besides, so that a strong jerk will frequently dislodge the head from its moorings. In this manner we obtained a number of large specimens, the divers using principally their hands alone in forcing.

[1] Histoire Naturelle des Coralliaires, II, p. 474 (Heliastræa.)

[2] The Mexican form agrees absolutely with a coral from the Post-Pliocene deposits of Santo Domingo, contained in the collections of the Academy, and which has been determined by Pourtalès to be *O. cavernosa*. But in this form, as in its more western representative, the intercaliculars spaces are largely cellular.

This is the only *Mœandrina* that was found in these waters, and I searched in vain among our specimens for *M. labyrinthica*—at least, for that form which Dana identifies with Ellis's description and figure. I have little doubt that Ellis himself included in his species the form which is now referred to *M. strigosa*, but there certainly appears to be a well-marked difference between the two species. The upright and very thin calicular walls, and the closely packed septa (45–50 to the inch), plainly identify the Vera Cruz species with Dana's *M. strigosa*. I found both species in the Bermudian waters.

Diploria cerebriformis, Lam.

This species is found in close association with the last, which in general habit and in coloring it also resembles. Both species are very numerously represented in all stages of development, and they build up a perfect pavement of coral—a pavement of giant cobble-stones, as it were. Their weathered masses are seen everywhere in the old stone constructions of Vera Cruz, where they constitute the true *piedra de mucar*.

Both species of brain-coral rise to within a very short distance of the surface, and we nowhere found them to descend below about 25 feet; usually they keep within a zone of some 5—15 feet. They occur closely packed, and where largely developed, in a way monopolize a given area, to the exclusion of the upright *Madreporaria*.

Oculina sp.?

I obtained a fragment of a species of this genus, but unfortunately it was misplaced before I had a chance to determine its specific characters.

Cladocora (Caryophyllia) flexuosa, Lamarck, Anim. Sans. Vert., 2d. Ed., II, p. 352. Ellis and Solander, "Zoophytes," pl. 32, fig. 1. (no description). Lamouroux, Expos. Méthod, Polypiers p. 49, pl. 32, fig. 1.

I identify with this species a form that is found in bunched masses on the bases of some of the Mæandrinas and gorgonians, and agrees well with the figures of Ellis and Solander, and with the descriptions furnished by the authorities above quoted and by Dana ("Zoophytes," p, 381). Lamarck doubtfully refers the species to the Indian Ocean, but Dana, more correctly, believes it to be West Indian. Verrill, in his synonymic list of species described by Dana, appended to the latter's "Corals and Coral Islands," doubtfully identifies the form in question with *Cladocora stellaria*, of Edwards and Haime (*Annales des Sciences Naturelles* Ser. 3, Zoology, XI, p.

307—X, pl. 7, figs. 9, 9a). This identification is, I believe, erroneous. *Cladocora stellaria* is a Mediterranean species, and is distinguished by a shallow cup; in the form from the Mexican Gulf the cup is deep, almost profound. The species is likewise distinct from that figured as *Cladocora arbuscula* in Agassiz's report on the Florida Reefs.

Plexaura (Gorgonia) flexuosa, Lamour. *Gorgonia anguiculus*, Dana (U. S. Exploring Expedition, Zoophytes, p. 668.)

This is the only species of gorgonian that we obtained in the Vera Cruz waters, but I have little doubt that others are present. We observed, however, none of those large Gorgonia fields which so beautify the waters of the Bermudas and excite the wonder of the visitor to those islands.

We obtained from the shallows about Progreso, northern shore of Yucatan, the *Xiphigorgia anceps* of Pallas (Elenchus Zoophytorum, p. 183). The species is fairly common there. I feel confident that the *Xiphigorgia Guadalupensis* of Duchassaing and Michelotti (Mémoire sur les Coralliaires des Antilles, Mem. Accad. Torino, 2d ser., XIX p. 309, pl. IV, fig. 3) is only this species, and likely the same is true of *X. Americana* of these authors (*Op. cit.*, XXIII (2d ser.) p. 113, pl. II, fig. 6). These investigators, while furnishing good illustrations of their material, have been singularly unfortunate in their determinations and descriptions of species.

The Reefs.

The reefs of the Vera Cruz waters consist of a number of detached islands or island banks, from less than half a mile to a mile and a half in length, which extend eastward from the coast line for a distance of nearly six miles. They are known as the Gallega (on which is built the famous Castle of San Juan de Ulúa) Galleguilla, Blanquilla, Anegada de Adentro, Isla Verde, Islote de Pajaros and Sacrificios. Of these, the Gallega, which is separated medially by a channel of water of moderate depth, is the largest, measuring in a north-and-south direction, considerably over a mile. Two other banks of very much smaller dimensions are the Lavandera, lying to the southeast of Gallega, and Terranova, between Sacrificios Island and the Islote de Pajaros. The outer boundaries of these reefs enclose a triangular body of water whose base is the coast line and whose apex is the Anegada de Adentro.

A second series of reefs begins about eight miles to the southeast, or opposite the promontory of Anton Lizardo, and likewise extends triangularly out to sea. The islets of this series (Arrecife de Cho-

pos, Medio, Cabeza, Anegada de Afuera, etc.) are considerably larger than those of the first, the Chopos reef measuring nearly three miles in length (N. W.—S. E.) Owing to the limited time at our command, we were unable to visit these lower reefs, and from personal observation, therefore, I am unable to say in how far they are purely of coral structure. But from the statements of those who are acquainted with the waters, I gather that they are largely identical in formation with the islets lying off Vera Cruz, and their general position and direction lead me to infer that they have a common origin. On the hydrographic charts all the dangerous banks are marked as reefs, but this should not be taken to necessarily mean "coral reefs." Thus, the reefs off Punta Gorda, lying 3–4 miles to the northwest of Vera Cruz, I found to be serpuloid and not coral, and the same is true, in great measure, of the Hornos reef, which lies about a mile to the southeast of the city. It should also be stated that the "coral sand" of hydrographic charts is not necessarily a sand of triturated coral, but may be of other limestone formation.

An examination of the accompanying maps (Pl's. VI and VII) shows that the main axis of nearly all the islands is directed in a N. W. —S. E. line, or in a direction parallel with the coast, a condition doubtless due to the interaction of prevalent winds and local currents, the latter of which shape the position of the detrital material. This is well shown by the heaps of shingle, coral-fragments, shells, etc., which have accumulated on the southeastern faces of some of the banks—the general lee-side of both wind and current—either as the result of long-continued action or of a single storm. Such deposits are especially well developed on Blanquilla and the Isla Verde; the island portion of the Sacrificios reef is likewise situated in the southeastern half of the circle of coral by which it is surrounded. Much the same contours that we see in the banks to-day already existed a century ago, as may be learned from the magnificent chart prepared by Ponzoni, in 1807, for the use of the Spanish Hydrographic Service.[1] This shows that the dry mass of Blanquilla already then

[1] This extremely rare map of the harbor of Vera Cruz, of which, I am informed, only two copies exist to-day in the whole of Mexico, was published in 1816. It is by far the most detailed of all the maps illustrating this portion of the Gulf waters, and it is especially interesting in connection with the study of coral reefs, as it carries back the authentic history approximately one hundred years. For the use of this map, and the permission to make a copy of it, I am indebted to Captain Powell, of Vera Cruz, Chief of Construction of Docks of the Mexican Railway. To the same gentleman, and to Messrs. Hall and Santiago Shirley, representing also the Mexican Railway, I am further indebted for many facilities offered for the exploration of the reefs and the accomplishment of our mission generally.

existed, but an additional structure, in the form of a stone wall much resembling a piece of masonry, has been superadded as the result of a single heavy storm, the hurricane of Sep. 8, 1888.

All of the reefs receive a breaking water, caused by the up-throw of disjointed boulders, and the heavier break is on the lee or shore-side, where the rock-masses have accumulated in greatest abundance. The long rolling surf, occurring in scattered patches over the blue waters, is a beautiful sight of the harbor. The more or less regularly oval shape of the reefs recalls the atoll-form, and a hasty examination of the region might lead to the assumption that the islets are true atolls. But this is not the case. It is true that a circular or elliptical form distinguishes some of the reefs, and that in others a patch of dry land is found surrounded by a more or less continuous ring of coral and a separating channel of water; but the conditions as they are presented are not those of true atolls. The form is that of almost any bank that rises either out of the water or close to its surface—the tendency of water-action being to round off the obstructions that may interpose themselves—and the included water is only a shallow pan, and not the distinctive lagoon of an atoll. The depth of water over the reefs generally is inconsiderable, from one and a half to perhaps six or seven feet, and some of the reefs are almost laid dry in low-water. This was the condition of the Gallega Reef when we finally left the harbor of Vera Cruz. The actual "ring" of the reefs, where it exists at all, is thus necessarily insignificant, and it is largely due to the mechanical action of water; in some parts it may arise from accelerated organic growth, but on this point I could not satisfy my mind. Be this as it may, the lagoon is certainly neither a lagoon of solution nor one of subsidence.

In the case of some of the reefs, as Gallega and Galleguilla—indeed, I am not sure if this is not true of most of the reefs—the greatest development of coral growth seems to be on the lee- or shore-side, or opposite to that which is generally supposed to receive the greatest supply of organic particles. The brain-corals and madrepores are there developed in immense profusion, although barren areas of sand here and there project themselves into the living mass. The scarcity of animal life on these sand tongues or patches is very remarkable; for long reaches we saw absolutely nothing in the shape of animal existence, while at other points there may have been a few shells (*Triton, Murex*) thinly scattered about. We

did not see a single starfish, nor were we more successful in our search after holothurians; the latter animals are especially conspicuous on the corresponding sands of the Bermuda Reefs. Far otherwise was it among the growing heads of coral, although even here the luxuriance of the Bermudas was wanting. The *Diadema setosa* among sea-urchins was very plentiful, and we observed a number of large annelids, besides mollusks of various kinds. But the bristling forest of millepores and sea-fans (gorgonians) was wanting, and with them the host of brilliantly colored forms which live in association.

The water separating the reef-patches is of moderate depth, but at many points it descends below the 20–fathom line, or beyond what is generally considered to mark the zone of living-reef structures. Thus, for most of the distance between the Isla Verde and Blanquilla (a little more than a mile and a half) the depth exceeds 100 feet, and at several places it varies from 120 to 130 feet; and much the same depth is found between Blanquilla and Galleguilla (one mile) and between the Isla Verde and the Islote de Pajaros (somewhat over a mile). We frequently sounded in these greater depths, and nowhere obtained positive indications of a coral growth; the greased lead invariably brought up sand particles, but no impressions of either dead or living corals. I could not say positively, however, that living corals may not be found in these deeper parts, as our "grease" was perhaps a little too soft to retain distinct impressions; but it is certain that wherever our sight penetrated the perfectly crystal waters to a depth exceeding 30–35 feet it fell on barren sand; and I am not sure that we anywhere could see living coral even at this depth. Usually the barren sands bounded the reef-zone at a depth lying between 15 and 25 feet.

The oceanic slope of the reefs is in most part a very moderate one, but there are places where it is as much as 1 in 5 or even 1 in 4 (12–14 degrees). Of course, this is small in comparison with that which is found in the case of many true atolls. Off the western point of the Islote de Pajaros we obtained 75 feet at a distance of little more than 200 feet from the breaking crest. As regards the permanence in depth of the water-ways between the reefs it may be said that many of our soundings corresponded absolutely with the soundings registered in the Ponzoni map of 1807 (1816). This correspondence was especially noticeable in the water-ways between the Islote de Pajaros and the Isla Verde and between the latter and

Blanquilla. On the other hand, immediately west of the Islote de Pajaros, and at various points southeast and south of Gallega, there seems to have been a considerable amount of shoaling, some places to the extent of 8 or 10 feet, or more, but in most parts I suspect that this shoaling is due almost wholly to the displacement of shifting sands, and not to coral encroachment. Apart from the testimony of the depth of water which is still found over these shallows, this condition seems to be largely indicated by the circumstance that at a few points a greater depth was found than appears on the map, probably the result of uncovering. It is not improbable that at a few places south of the Gallega Reef, or between the reef and the mainland, the shallowing that we observed is actually due to coral up-growth; at any rate, the discrepancy in the depths is here very marked, as much as 12–15 feet (depth of water 21–27 feet), and the waters cover a rich growth of brain-coral (*Mœandrina, Diploria*). It is hardly possible that a layer of corals approaching so closely to the surface should have completely escaped the early hydrographers, or that these investigators could have been in error in their determinations of the then existing depths. But then if neither proposition is tenable, and we are compelled to fall back upon the assumption of simple coral up-growth—which to me appears every way plausible—we must assume a rate of growth much more rapid than has until recently been allowed these lowly organisms. A number of instances are, however, on record where individual specimens of *Mœandrina* are known to have increased in height from a half-inch to an inch per annum, and of *Madrepora* where the increase for the same period has been three inches.[1] An average growth of an inch and a half per year would add in a period of ninety years eleven feet.

The reefs which have been described in the preceding pages manifestly belong to that group which Darwin recognized as being

[1] Dana "Corals and Coral Islands," 2d ed., 1890, pp. 123–127 (quoting Pourtalès, Hunt, Verrill, etc.). On the other hand, the observations of Mr. H. T. Woodman (communicated to Prof. Dana under date of Jan. 25th, 1890—*Op. cit.*, appendix, pp. 418–419), conducted over a period of fourteen years, would seem to indicate a very much slower growth. During the above-mentioned period the following upward growths (among others) were registered: *Orbicella annularis*, one and a quarter inches; *Diploria cerebriformis*, nearly three-fourths of an inch; *Mœandrina sinuosa*, an inch and a quarter; and *Mœandrina labyrinthica*, an inch and seven-eighths. Specimens of *Madrepora cervicornis*, however, seem to have encroached upon the channel under observation to an extent of 6–8 or even 10 feet.

built upon shoals or beds of sediment "lying a little beneath the surface, ready to serve as the basis for the attachment of coral" ("Structure and Distribution of Coral Reefs," 1842, p. 58), a class of structures which the opponents of the subsidence theory of reef-formations fail to recognize as being in consonance with the Darwinian hypothesis. They are, according to a strict classification, neither encircling, barrier, nor fringing reefs, and as a fourth class might, perhaps, with advantage be grouped as "*patch*" reefs. They belong to the same category as the Florida reefs and banks, whose formation has been largely appealed to as evidence against the Darwinian hypothesis of subsidence. But neither the Florida reefs nor the reefs of Vera Cruz give any evidence either in favor of or against great subsidence, since they are mere shallow-water formations, and, so far as direct evidence goes, they represent only surface deposits. Yet it is by no means either impossible or improbable that some of them are actually placed on subsided areas, while it is all but positive that others have been brought to their present positions through elevation. Certain it is that movements of elevation have taken place in the Floridian region during a very recent geological period, and it is at least probable that movements in a contrary direction were not wanting at about the same, or a somewhat earlier, period, and again later.[1] In the case of the Vera Cruz reefs we have more

[1] I have discussed these points in my report on the geology of the peninsula of Florida ("Explorations on the West Coast of Florida and in the Okeechobee Wilderness"—Trans. Wagner Free Institute of Science, Phil., 1887—pp. 15, 26–33, 64b), and again in my observations on the coral reefs of the Bermudas ("The Bermuda Islands. A Contribution to the Physical History and Zoology of the Somers Archipelago," 1889—pp. 61, 73, 227). Alexander Agassiz well recognizes the nature of the "patch" reefs, and the possibilities of their formation (following Darwin) without the necessity of either elevation or subsidence ("The Tortugas and Florida Reefs." Memoirs Amer. Acad. Arts and Sciences, XI, part. II, 1885, pp. 118–19). But I fail to see the evidence in support of the statement that "on the Yucatan, as on the Florida Bank, the conditions favorable for coral reef growth have been produced, not by the uplifting of the continent, but by the gradual rising of the bank itself into suitable depths in consequence of the accumulation of animal *débris* upon it" (*loc. cit*); or for the further statement that "there is practically no evidence that the Florida reef, or any part of the southern peninsula of Florida which has been formed by corals, owes its existence to the effect of elevation" ("Three Cruises of the Blake," I, p. 61, 1888). In my work on the Bermuda Islands, above referred to, I have considered these points, and attempted to show that the actual geological evidence that we possess in the premises tends largely, I might say, almost wholly, to a conclusion opposite to that which was reached by Mr. Agassiz. Prof. Shaler, in a

definite data regarding the condition of the surface upon which those structures are reared. The position San Juan de Ulúa, on the Gallega Reef, is evidence that there have been no changes of level of any consequence for at least 300 years, or since the year (1582) when the construction of the fort was first begun; the recent development of the reefs has been in a stable area.

Manifestly, in a region of stability there could have been no "atolls of subsidence" formed, and we find no reefs that can even remotely be associated with the atoll structure. The facts thus far neither favor nor oppose the Darwinian theory of coral formations, but they are fully in consonance with it; and, so far as I see, they neither favor nor absolutely disprove the substitute theory which has been advanced by Mr. Murray and his followers. It is, however, a significant (if perhaps not remarkable) circumstance that with peripheral acceleration (in growth) and internal solution—the two determining conditions of atoll formation of most of the adherents of the new school—we should still fail to find in a region of stability, atoll-reefs. It is true that, with the very slow rate of solution which has been assumed to be possible, a well or lagoon of any depth could barely be formed in a period of three hundred years;

somewhat singular paper on "The Topography of Florida"—singular for reason of its failing to take account of the geological work done in the State prior to his own researches—supplements my proof of the geologically recent uplift of the southern portion of the Floridian peninsula with testimony bearing directly upon the reefs themselves: thus the reef of Biscayne Bay "gives proof of a recent elevation of the shore to the height of about twenty-five feet" (Bull. Mus. Comp. Zool., XVI, 1890, p. 143). This statement is, of course, directly antagonistic to the position held by Mr. Agassiz. In my description of the rocks of Sarasota Bay, west coast of Florida (Trans. Wagner Free Inst. Science, 1, 1887, p. 15), I state that it is "more than probable that this portion of the coast has quite recently been undergoing subsidence"; Prof. Shaler (*Op. cit.*, p. 148) corroborates this position by the statement: "There is a good deal of evidence to the effect that the whole peninsula of Florida has undergone a subsidence of ten or twenty feet in altitude since the last period of elevation."

With direct evidence thus in favor of both elevation and subsidence of the Floridian region during the existing period of coral-growth, nothing remains of the assumption that the formation of the Florida Reefs is in any way opposed to the Darwinian theory of reef structure, for it absolutely nullifies the three leading propositions that are embodied in that assumption: 1. That there has been no subsidence in the coral making tract; 2, that there has been no elevation in the same region; and 3, that great banks, organically constructed, have been built up without assisting movements of the crust. The same argument applies to the reefs of the Yucatan bank.

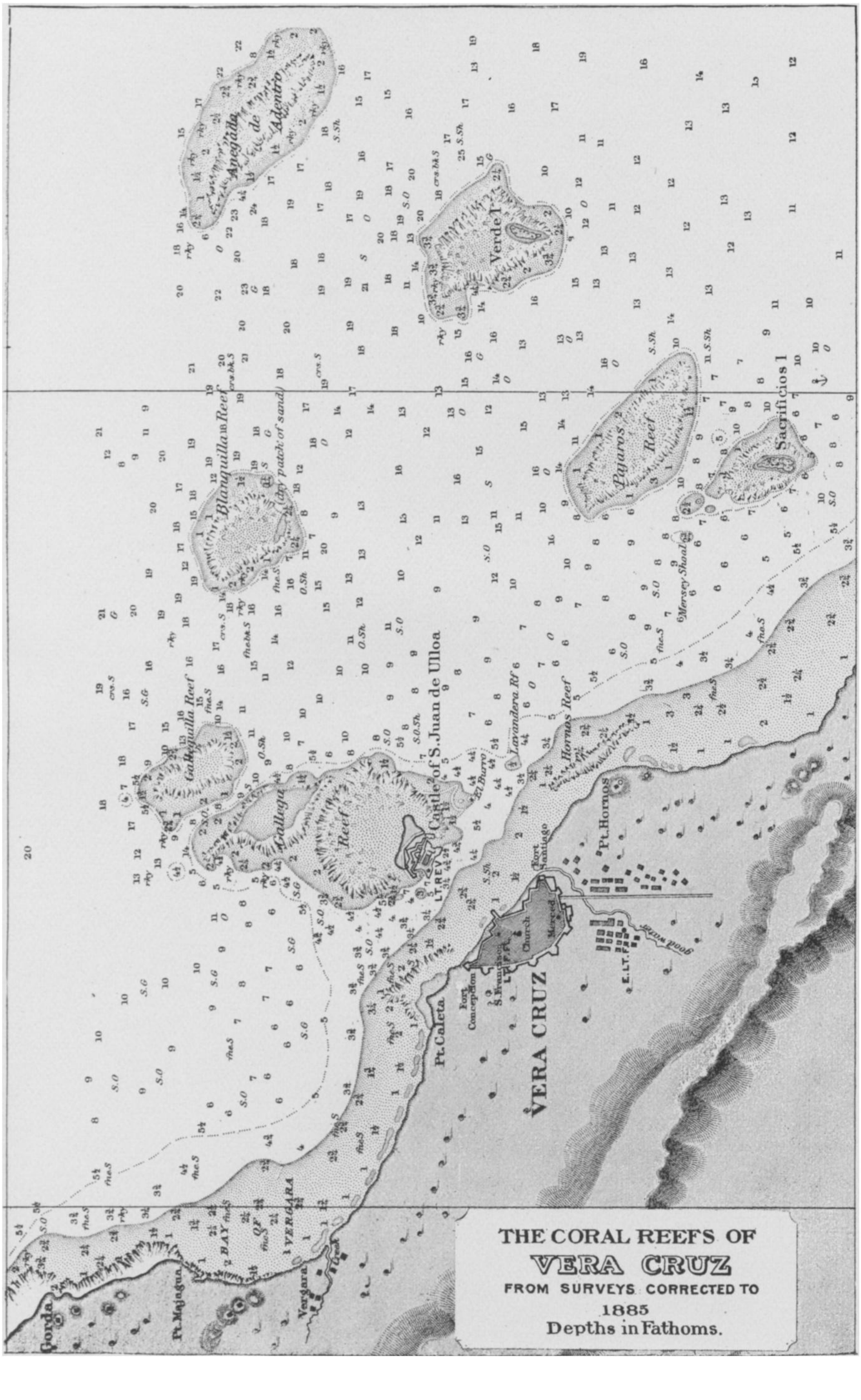
the rate of $\frac{1}{10}$ inch per annum, which has been assumed by Irvine,[1] would yield in this period of time a depth of water no greater than actually exists on some of the reefs to-day, about two or three feet.[2] But then it should not be forgotten that the three centuries represent merely the least time for which we have a record of the completion of a single reef; the identical condition of stability may have existed for centuries before, and certainly a long period was consumed in the growth of the reef before it reached the surface. Surely some decided evidence of solvent action, in the form of a true basin-structure, might have been expected in this time; and the more if we further take into account peripheral acceleration. But such evidence is clearly wanting. So little, however, is as yet known regarding the amount and capabilities of solution that, perhaps, too much stress should not be laid upon this negative evidence—especially, as we seem to be dealing with a somewhat mysterious force, whose workings are, at least to me, a little inscrutable. The solvent "power" that permits to build up and then, apparently without cause, suddenly reverses and begins to remove, is possessed of a

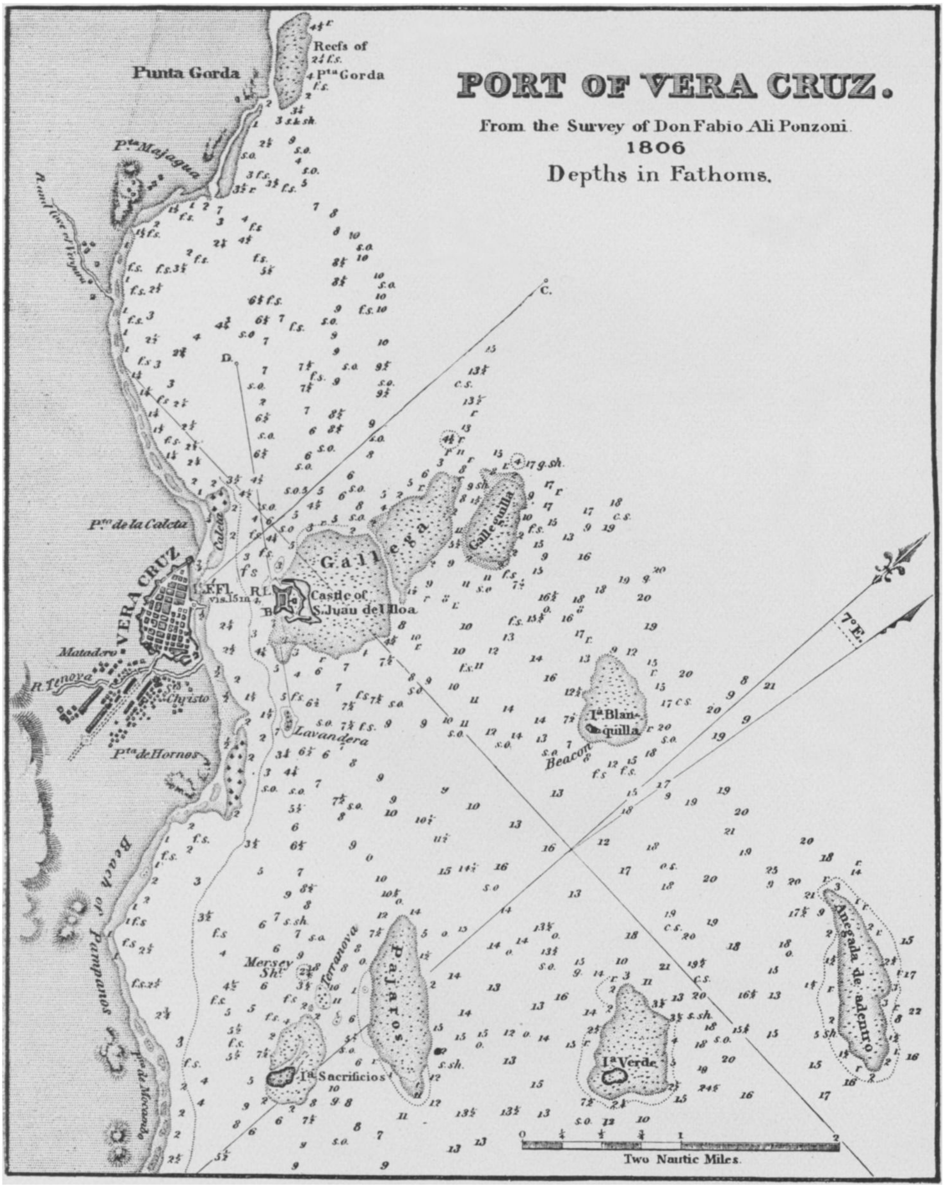
Mr. Agassiz, in a note to Prof. Shaler's paper, seems to think that the Florida Everglades may be largely of a reef formation, or to be due to sedimental accumulation behind and between reefs. This is a revival in part of the old reef-theory of growth of the Floridian peninsula, which recent researches have abundantly disproved. Mr. Agassiz recognized that this theory is no longer tenable, but he manifestly lays too much stress upon the probability of a like structure holding good for that part of the peninsula which lies south of the "northern extremity," or even for that which is mainly comprised within the region of the Everglades itself. My own researches, which have since been supplemented by those of Dr. Dall, show that heavy fossiliferous deposits of Pliocene age are found nearly half across the peninsula on the Caloosahatchie, and their position there makes it practically certain that they largely underlie the region of the Everglades. I have so stated it in my report (p. 65): "The evidence, further, is very strong that beyond Lake Okeechobee and the Caloosahatchie the structure of the State is for the most part identical with that above it, and the observed facts clearly prove that this correspondence must exist over at least a considerable portion of the unexplored region of the Everglades." Mr. Agassiz has apparently not read my report (beyond possibly the opening sentence), otherwise he could hardly have stated (p. 157) that my "explorations were limited to the portions of the west coast of Florida included between Cedar Keys and Punta Rassa, and did not touch the Everglade district."

[1] Nature, March 15, 1888; this point is discussed in my "Bermuda Islands," pp. 203–205, 1889.

[2] It has already been remarked that the central reef-depression is in most cases merely a negative one, a rim having been formed through up-throws by the beating waters.

capacity for work which requires special examination. Individually, I must confess, I have thus far failed to find a fragment of a fact which supports the solution theory of lagoon-formation; and so long as the construction of the reef-lagoon remains unexplained, so long must all theories explaining the formation of atolls be considered defective.


THE CORAL REEFS OF
VERA CRUZ
FROM SURVEYS CORRECTED TO
1885
Depths in Fathoms.
Anegada de Adentro
Verde I.
Blanquilla Reef
Pajaros Reef
Sacrificios I.
Galleguilla Reef
Gallega
Reef
Castle of S. Juan de Ulloa
Lavandera Rf.
Hornos Reef
Mersey Shoal
Pt. Hornos
Pt. Caleta
VERA CRUZ
Pt. Majagua
Gorda
Vergara


PORT OF VERA CRUZ.
From the Survey of Don Fabio Ali Ponzoni.
1806
Depths in Fathoms.
Punta Gorda
Reefs of Pta Gorda
Pta Majagua
Pto de la Caleta
VERA CRUZ
Castle of S. Juan de Ulloa
Gallega
Gallegnilla
Matadero
R. Tenoya
Sto Christo
Lavandera
Pta de Hornos
Beach of Pampanos
Ia Blanquilla
Beacon
Mersey Shl
Terranova
Pajaros
Ia Sacrificios
Ia Verde
Anegada de adentro
7°E.
Two Nautic Miles.